Image analysis of a nuclear plasma: Frascati Tokamak Upgrade using IDL and ENEA-GRID technologies

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Introduction

Today a number of applications in scientific fields (such as medical industry, astronomy, physics, chemistry, forensics, remote sensing, manufacturing, defense) rely upon images to store, display, and provide information about the world around us. The challenge to scientists, engineers and business people is to quickly extract valuable information from raw image data. The primary purpose of our work (within CRESCO Project) - i. e. converting images of a nuclear fusion plasma coming from the experiments (shots) of Frascati Tokamak Upgrade (FTU) into information (Fig. 1) by ENEA-GRID infrastructures-is related to such issue. In particular, we use IDL (Interactive Data Language) in order to quickly access image data and to process them. IDL is a high-level programming language that contains an extensive library of image processing and analysis routines.

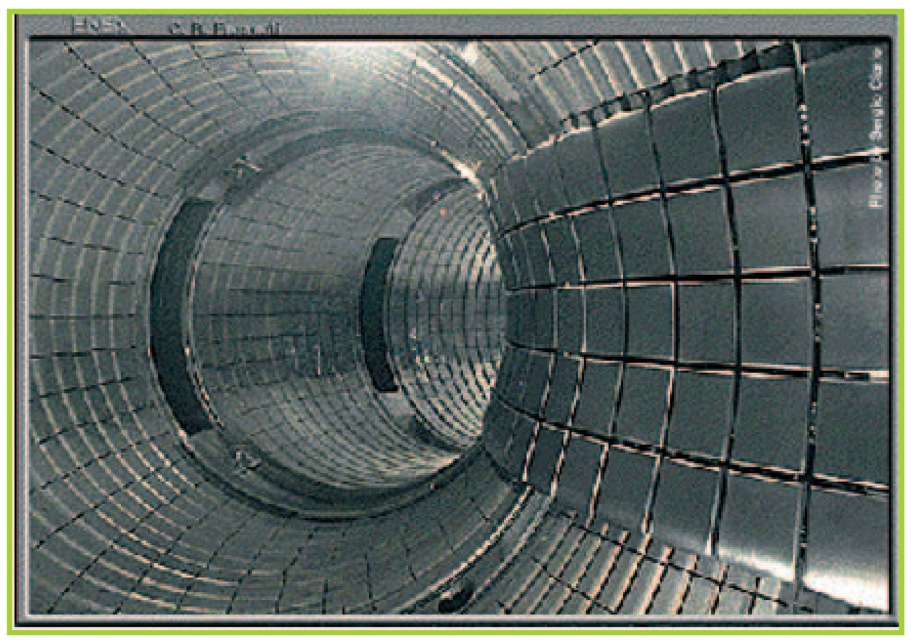

Figure 1 An internal view of the Frascati Tokamak Upgrade vessel. The limiter is shown in the central part of the chamber.

Setting

In modern tokamaks visible and infrared video cameras are becoming more and more important to monitor plasma evolution during fusion experiments. The real-time analysis of FTU images performed by IDL applications (Falsecolor, Database, Volume, Brightzone) can really provide relevant information to control the plasma and the safety of the machines.

Problem: In the last years video cameras have been extensively used in magnetic confinement fusion experiments for both the understanding of the physics and the safety of the operation. Both visible and InfraRed (IR) images can be used not only to monitor the evolution of a plasma discharge but also to evaluate specific parameters, from the determination of impurity radiation to the distribution of power loads on the plasma facing components. Data analysis is normally performed offline, due to the high amount of information to be processed, making the data acquired by the camera quantitatively useful only for post pulse evaluations. The main difficulty in using visible or infrared images for plasma feedback control is the fact that real-time image processing is challenging and heavy in terms of processing time, especially when complex tasks are required.

Novelty: At the beginning, the visualization of FTU images has been done under the Videoftu Project. Since FTU image database is rather huge ($4x10^6$ Frames), we used the multicase submission with multicluster queue to achieve efficient performance in terms of elapsed time and CPU time. In order to reduce the run-time of the processes, the route of multicase processing has been utilized.

IDL and ENEA-GRID

In CRESCO Project, under the task "Development and Integration of the GRID and 3D Graphics" we ported a number of applications which analyse and elaborate the images coming from the tokamak database.

Goal: Image and processing analysis of FTU data through IDL applications: Falsecolor, Database, Volume, Brightzone. In details, the applications allow image quality improvement (noise reduction, contrast enhancement, distortions correction), automatic classification by pattern recognition algorithms and brightness analysis, used to detect images with a characteristic feature (quite recurrent in the plasma) in the brightness distribution. An example is the detection of bright toroidal bands (i.e. lying in the vessel' s equatorial plane), which precede the onset of regimes of enhanced gas recycling on the wall (a phenomenon known in tokamaks as 'Marfe'), sometimes followed by distructive events. A second example is the identification of bright spots, characterised by typical shapes and localization, which are due to high energy electrons ('runaway electrons'), potentially dangerous for the vacuum chamber. The applications allow a large number of tokamaks images's classification according to specific events and help understanding their correlation with other physical quantities. On the other hand the achievement of event recognition on timescales shorter than those of the evolution of unwanted events, can provide a useful input for the feedback control of plasma operations.

Method: The experimental evaluation of the algorithm in IDL environment has been performed through the use of the ENEAGRID infrastructures for the submission and the execution of jobs (Fig. 2-3). We used the multicluster queue to achieve efficient performance in terms of elapsed time. Hence, the experimental evaluation of the algorithm in IDL environment has been performed through the use of the ENEA-GRID infrastructures for the submission and the execution of jobs.

Example of Application

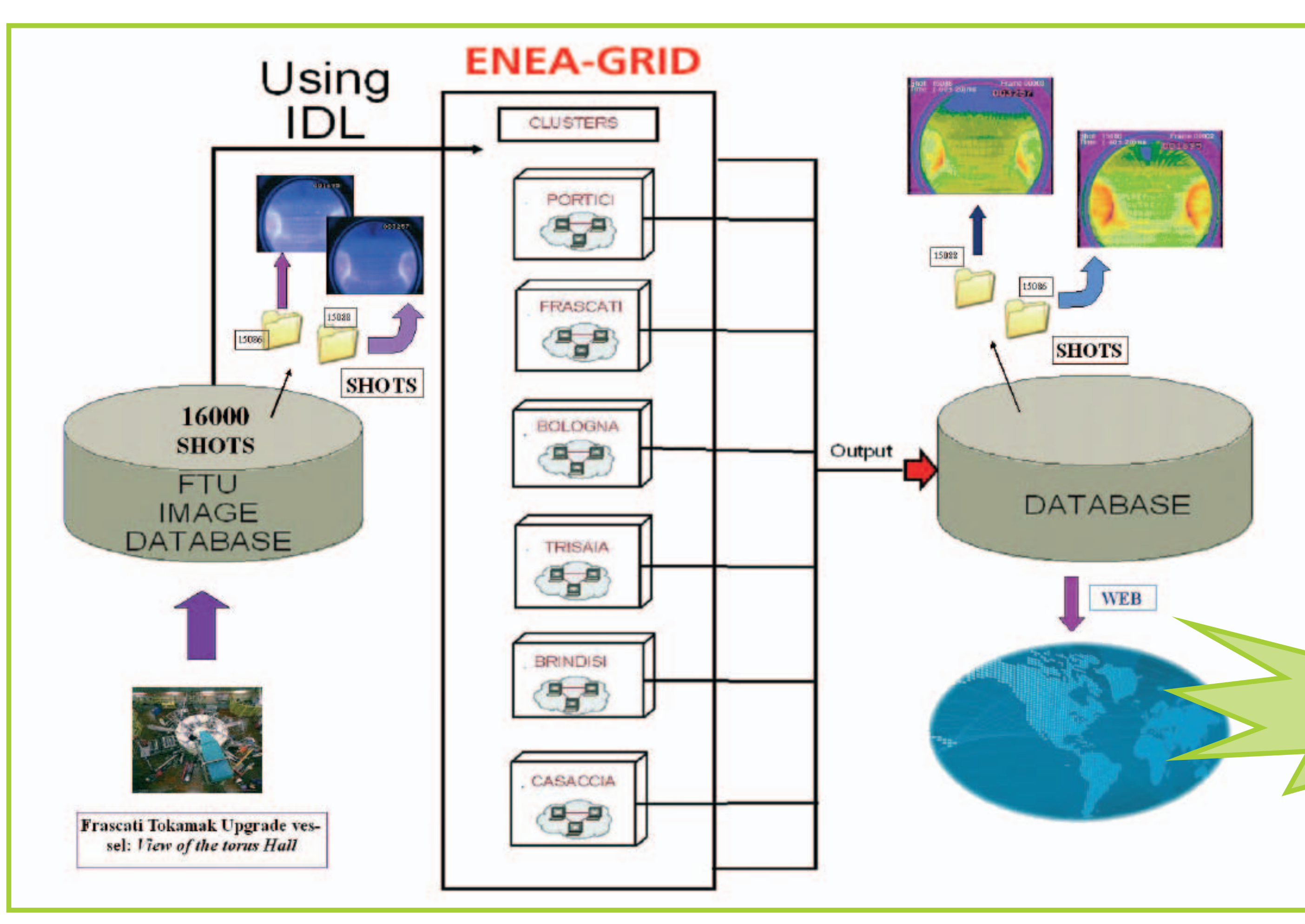

Figure 2 FTU images are input database ($4X10^6$ Frames). We have used the IDL resources in ENEA-GRID infrastructures for the submission and the execution of jobs. In details, we used the multicase submission with multicluster queue that run applications simultaneously on the 6 ENEA-GRID clusters (Portici, Frascati, Bologna, Trisaia, Brindisi, Casaccia) in order to achieve efficient performance in terms of ELAPSED and CPU time: benchmark tests we carried out on different platforms with different type of queue show real and meaningful performance improvements in running jobs by opting for this scheduling solution. The images analysis of FTU data through IDL applications are in the output.

The utilization of the ENEA-GRID technology is an efficient solution to reduced the run-time required to execute the simulations

IDL and ENEA-GRID submission: Experimental result with multicluster queue

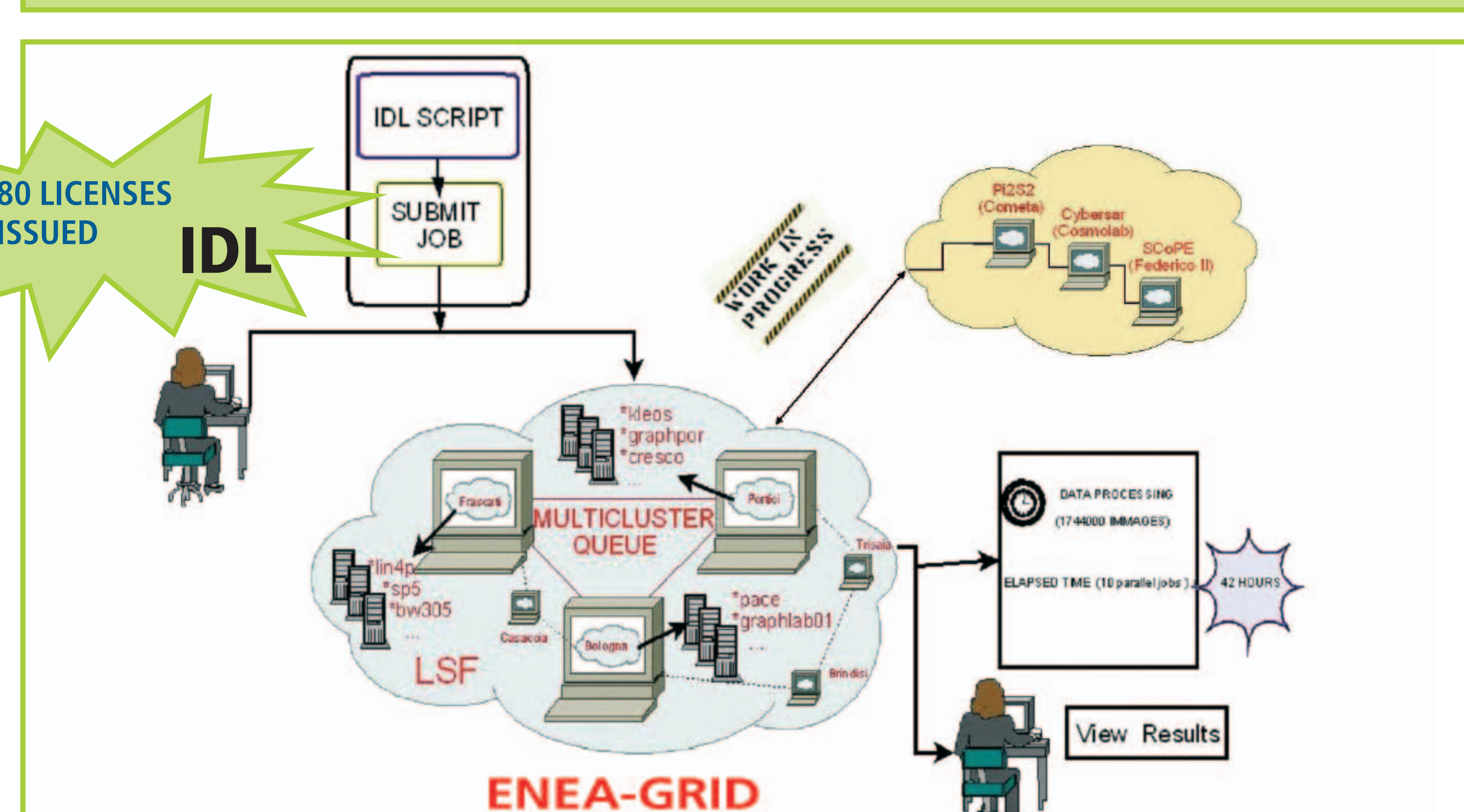

Figure 3 Benefits of multicluster queue. For example, let's con-sider an FTU experiment where a range of 20 shots (each shot con-tains 109 frame) is produced by a single job:

CPU TIME: ≈ 12 min
CPU TIME (DATABASE): ≈ 160 hours

Experimental Tests with distributed run:

ELAPSED TIME (10 parallel jobs): ≈ 17 hours
ELAPSED TIME (30 parallel jobs): ≈ 6.2 hours
ELAPSED TIME (60 parallel jobs): ≈ 3.5 hours

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